# IN THE UNITED STATES PATENT AND TRADEMARK OFFICE


In re Patent Application of
NAKAMURA et al

Serial No. 10/718,652

Filed: November 24, 2003

Atty. Ref.: 160-399

TC/A.U.: 2828

Examiner:

For: NITRIDE SEMICONDUCTOR WITH ACTIVE LAYER OF QUANTUM WELL STRUCTURE WITH INDIUM-CONTAINING NITRIDE SEMICONDUCTOR

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May 3, 2004

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

## INFORMATION DISCLOSURE STATEMENT

Listed on accompanying Form PTO-1449 are documents that may be considered material to the examination of this application, in compliance with the duty of disclosure requirements of 37 C.F.R. §§ 1.56, 1.97 and 1.98.

Applicants have listed publication dates on the attached PTO-1449 based on information presently available to the undersigned. However, the listed publication dates should not be construed as an admission that the information was actually published on the date indicated.

Applicants reserve the right to establish the patentability of the claimed invention over any of the information provided herewith, and/or to prove that this information may not be prior art, and/or to prove that this information may not be enabling for the teachings purportedly offered.

This statement should not be construed as a representation that a search has been made, or that information more material to the examination of the present patent application does not exist. The Examiner is specifically requested not to rely solely on the material submitted herewith. It is further understood that the Examiner will consider information that had been cited by or submitted to the U.S. Patent and Trademark Office in a prior application relied on under 35 U.S.C. § 120. 1138 OG 37, 38 (May 19, 1992).

Applicants have checked the appropriate boxes below.

1. ☒ This Information Disclosure Statement is being filed within three months of the U.S. filing date OR before the mailing date of a first Office Action on the merits. No statement under 37 C.F.R. § 1.97(e) or fee is required. In the event, a first Office Action has been mailed prior to filing of the present Information Disclosure Statement, the Office is requested to treat the present paper s a submission under 37 C.F.R. § 1.97(c) and charge the undersigned's Deposit Account No. 14-1140 for the fee required by 37 C.F.R. § 1.17(p). The present paper is submitted in duplicate for this purpose.

2. ☐ This Information Disclosure Statement is being filed more than three months after the U.S. filing date AND after the mailing date of the first Office Action on the merits, but before the mailing date of a Final Rejection or Notice of Allowance.

   a. ☐ I hereby state that each item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement. 37 C.F.R. § 1.97(e)(1).

   b. ☐ I hereby state that no item of information in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to my knowledge after making reasonable inquiry, no item of information contained in this Information Disclosure Statement was known to any individual designated in 37 C.F.R. § 1.56(c) more than three months prior to the filing of this Information Disclosure Statement. 37 C.F.R. § 1.97(e)(2).

   c. ☐ Attached is our Check No. in the amount of $ in payment of the fee under 37 C.F.R. § 1.17(p).

3. ☐ This Information Disclosure Statement is being filed more than three months after the U.S. filing date and after the mailing date of a Final Rejection or Notice of Allowance, but before payment of the Issue Fee. It is hereby requested that the Information Disclosure Statement be considered. Attached is our Check No. in the amount of $ in payment of the fee under 37 C.F.R. § 1.17(i).

a. ☐ I hereby state that each item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement. 37 C.F.R. § 1.97(e)(1).

b. ☐ I hereby state that no item of information in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to my knowledge after making reasonable inquiry, no item of information contained in this Information Disclosure Statement was known to any individual designated in 37 C.F.R. § 1.56(c) more than three months prior to the filing of this Information Disclosure Statement. 37 C.F.R. § 1.97(e)(2).

4. ☐ Relevance of the non-English language document(s) is discussed in the present specification.

5. ☐ The document(s) was/were cited in a corresponding foreign application. An English language version of the foreign search report is attached for the Examiner's information.

6. ☐ A concise explanation of the relevance of the non-English language document(s) appears below:

7. ☐ The Examiner's attention is directed to co-pending U.S. Patent Application No. , filed , (copy attached) which is directed to related technical subject matter. The identification of this U.S. Patent Application is not to be construed as a waiver of secrecy as to that application now or upon issuance of the present application as a patent. The Examiner is respectfully requested to consider the cited application and the art cited therein during examination.

It is respectfully requested that the Examiner initial and return a copy of the enclosed PTO-1449, and to indicate in the official file wrapper of this patent application that the documents have been considered.

The U.S. Patent and Trademark Office is hereby authorized to charge any fee deficiency, or credit any overpayment, to our Deposit Account No. 14-1140 referencing docket number 160-399.

Respectfully submitted,

**NIXON & VANDERHYE P.C.**

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INFORMATION DISCLOSURE CITATION

(Use several sheets if necessary)

| Atty. Docket No. | Serial No. |
|---|---|
| 160-399 | 10/718,652 |
| **Applicant** | |
| NAKAMURA et al. | |
| **Filing Date** | **TC/A.U.** |
| November 24, 2003 | 2828 |



## U.S. PATENT DOCUMENTS

| *EXAMINER INITIAL | | DOCUMENT NUMBER | DATE | NAME | CLASS | SUBCLASS | FILING DATE IF APPROPRIATE |
|---|---|---|---|---|---|---|---|
| ✓ | | 5,793,054 | 08/1998 | NIDO | | | |

## FOREIGN PATENT DOCUMENTS

| | | DOCUMENT | DATE | COUNTRY | CLASS | SUBCLASS | TRANSLATION YES | TRANSLATION NO |
|---|---|---|---|---|---|---|---|---|
| ✓ | | JP 6-164085 | 06/1994 | JAPAN | | | ABSTRACT | |
| | | JP 6-268259 | 09/1994 | JAPAN | | | ABSTRACT | |
| | | JP 6-268257 | 09/1994 | JAPAN | | | ABSTRACT | |
| | | JP 7-249795 | 09/1995 | JAPAN | | | ABSTRACT | |
| | | JP 8-070139 | 03/1996 | JAPAN | | | ABSTRACT | |
| | | JP 9-191160 | 07/1997 | JAPAN | | | ABSTRACT | |
| | | JP 7-235729 | 09/1995 | JAPAN | | | ABSTRACT | |
| | | JP 9-148247 | 06/1997 | JAPAN | | | ABSTRACT | |
| | | JP 9-148678 | 06/1997 | JAPAN | | | ABSTRACT | |
| | | JP 6-164055 | 06/1994 | JAPAN | | | ABSTRACT | |
| | | JP 9-116225 | 05/1997 | JAPAN | | | ABSTRACT | |
| | | JP 8-064910 | 03/1996 | JAPAN | | | ABSTRACT | |
| | | JP 8-116128 | 05/1996 | JAPAN | | | ABSTRACT | |
| | | JP 9-129925 | 05/1997 | JAPAN | | | ABSTRACT | |
| | | JP 8-316581 | 11/1996 | JAPAN | | | ABSTRACT | |
| | | EP 0 805 500 | 11/1997 | EP | | | X | |
| | | JP 7-235729 | 09/1995 | JAPAN | | | ABSTRACT | |
| | | | | | | | | |

## OTHER DOCUMENTS (including Author, Title, Date, Pertinent pages, etc.)


AKASAKI et al., "Stimulated Emission by Current Injection from an AlGaN/GaN/GaInN Quantum Well Device," Jpn. J. Appl. Phys., Vol. 34 (1995), pp. L1517-L1519

NAKAMURA et al., "High-power InGaN Single-Quantum-Well-Structure Blue and Violet Light-Emitting Diodes," Appl. Phys. Lett. , Vol. 67, No. 13 (1995), pp. 1868-1870

NAKAMURA et al., "Candela-Class High-Brightness InGaN/AlGaN Double-Heterostructure Blue-Light-Emitting Diodes," Appl. Phys. Lett. Vol. 64, No. 13 (1994), pp. 1687-1689

NARUKAWA et al., "Recombination Dynamics of InGaN Quantum Wells by Time-Resolved Photoluminescence," Technical Report of the Institute of Electronics, Information and Communication Engineers (Oct. 1996) (Japan), pp. 81-88

WAKAHARA et al., "Growth of GaInN Alloy Layer and Its Composition Inhomogeneity," Technical Report of the Institute of Electronics, Information and Communication Engineers (Oct. 1996) (Japan), pp. 15-20

NAKAMORI, T., "Unveiling the Structure of Pulse-Oscillate GaN Blue-Violet Semiconductor Laser," Nikkei Electronics (Jan. 1996) (Japan) No. 653, pp. 13-15

NAKAMURA, S., "Development of Blue Device in Final Stage," Electronics (Feb. 1996) (Japan), pp. 1-3

NAKAMURA, S., "Latest Progress in Nitride-Based Blue/Green LED and Semiconductor Laser," International Forum "Blue Light-Emission" Project of Hoso-Bunka Foundation, Inc. (May 1996) (Japan) pp. 53-60.


| *Examiner | | Date Considered | |
|---|---|---|---|

Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to application.

# Information Sheet for preparing an Information Disclosure Statement under Rule 1.56

Suzuye Ref : 96S0564-1DC2D

Foreign Patent Documents

Document No.: JP6-164085, published June 10, 1994
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP6-268259, published September 22, 1994
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP6-268257, published September 22, 1994
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP7-249795, published September 26, 1995
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP8-70139, published March 12, 1996
Country: Japan
Copy of reference: attached
Language: non-English

English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP9-191160, published July 22, 1997
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP7-235729, published September 5, 1995
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP9-148247, published June 6, 1997
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP9-148678, published June 6, 1997
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP6-164055, published June 10, 1994
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP9-116225, published May 2, 1997
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP8-64910, published March 8, 1996
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP8-116128, published May 7, 1996
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP9-129925, published May 16, 1997
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP8-316581, published November 29, 1996
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP9-129929, published May 16, 1997
(EP publication No: 805500 A1, published November 5, 1997)
Country: Japan

Copy of reference: attached
Language: non-English

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Document No.: JP7-235729, published September 5, 1995
Country: Japan
Copy of reference: attached
Language: non-English
English abstract: attached
Concise Explanation of Relevance: See the attached English abstract.

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Document No.: JP9-8412, published January 10, 1997
(U.S. publication No: US 5,793,054, published August 11, 1998)
Country: Japan
Copy of reference: attached
Language: non-English

Non Patent Literature Documents (English)

Reference: Jpn. J. Appl. Phys. Vol.34(1995) pp.L1517-L1519
Copy of reference: attached

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Reference: Appl. Phys. Lett. Vol.67, No.13(1995)p.1868-1870
Copy of reference: attached

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Reference: Appl. Phys. Lett64[13](1994) p.1687-1689
Copy of reference: attached

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Non Patent Literature Documents (non English)

Reference: Y. Narukawa et al., "Recombination dynamics of InGaN quantum wells by time-resolved photoluminescence",

TECHNICAL REPORT OF THE INSTITUTE OF ELECTRONICS, INFORMATION AND COMMUNICATION ENGINEERS, October 1996, (Japan), p.p. 81-88
Copy of reference (relevant pages): **attached**
English translation: **translation of related portions attached**

To investigate into the origin of this localization, the section was observed by TEM. FIG. 6 shows 0002 bright field image from [0110]. It is known from FIG. 6(i) that multiple quantum wells of well width of 30 angstroms and barrier width of 60 Å are formed. A magnified view of the quantum well portion is FIG. 6(ii). Multiple black spots are present in the quantum well. The size varies from 2 to 5 nm, but is mostly 3 nm. Considering the sample thickness (30 nm), the density is $5 \times 10^{11}$ to $2 \times 10^{12}$ $cm^{-2}$, and the volume density is estimated around 2 to 9%.

By rotating (30 degrees) the sample from [0110] to [1210], the shape of black spots was not changed, and thus, it seems that an isotropic quantum dot region is formed spontaneously.

Therefore, the origin of localized leveling is found to be a localized level of the quantum dot region in the quantum well. It is theoretically predicted by three-element mixed crystal of InGaN is likely to induce phase isolation, and spontaneous formation of InGaN quantum dots observed herein is considered to be derived from such a property of InGaN [18, 19].

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Reference: **A. Wakahara et al., "Growth of GaInN Alloy Layer and Its Composition Inhomogeneity", TECHNICAL REPORT OF THE INSTITUTE OF ELECTRONICS, INFORMATION AND COMMUNICATION ENGINEERS, October 1996, (Japan), p.p. 15-20**
Copy of reference (relevant pages): **attached**
English translation: **translation of related portions attached**

By waveform isolation of the GaInN diffraction peak, results of determining the In composition in the mixed crystal layer are shown in FIG. 6. As known from the diagram, the average composition of In decreases gradually along with elevation of growth temperature, and the composition is divided into two sections at growth temperature of 600°C or higher. In immiscible phenomena reported so far, the degree of composition separation is said to be severer as the growth temperature is lower [10], but the nonuniformity of the composition observed herein suggests an opposite temperature dependence of becoming severer as the growth temperature increases.

On the other hand, as a result of close investigation into the growth temperature dependence of the growth layer composition, it is found that the composition becomes nonuniform in the high temperature growth region of 600°C or higher.

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Reference: **T. Nakamori, "Unveiling the structure of pulse-oscillate GaN blue-violet semiconductor laser", NIKKEI ELECTRONICS, January 1996, (Japan), (No. 653), p.p. 13-15**
Copy of reference (relevant pages): **attached**
English translation: **translation of relevant portions attached**

Unveiling the structure of pulse-oscillated GaN blue-violet semiconductor laser

Multiple quantum well structure of 26 layers

Detail is disclosed about the blue-violet semiconductor laser that Nichia Chemical Industry Co. succeeded in room temperature pulse oscillation. The active layer is realized by 26-layer InGaN multiple quantum well structure. The resonance surface is the GaN multilayer film on a sapphire substrate processed by etching. The problem of continuous oscillation is a high applied voltage of 30 V. This is because the resistance is high at the junction of the p-type electrode and GaN layer. The company tells the problem can be solved soon.

FIG. 4 Structure of semiconductor laser.

Portion of multiple quantum well is a 26-layer structure of a pair of $In_{0.2}Ga_{0.8}N$ well layer and $In_{0.3}Ga_{0.95}N$ barrier layer. By inserting a p-type $Al_{0.2}Ga_{0.6}N$ layer on this structure, the laser performance is enhanced. Nichia Chemical Industry Co. explains that this layer functions to protect the InGaN layer which is likely to be decomposed by heat. The GaN buffer layer of the first layer on the substrate and the n-type $In_{0.1}Ga_{0.9}N$ layer on the n-type GaN layer are inserted in order to grow the upper layers by a higher crystal quality.

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Reference: **S. Nakamura, "Development of blue device in final stage", ELECTRONICS, February 1996, (Japan), p.p. 1-3**
Copy of reference (relevant pages): **attached**
English translation: **translation of relevant portions attached**

Trend of new multimedia and direction of technology development (1)

Development of blue device in final stage

FIG. 3 Structure of InGaN-based MQW laser diode.

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Reference: **S. Nakamura, "Latest progress in nitride-based blue/green LED and semiconductor laser", International forum "Blue light-emission for tomorrow imaging", Contract research by "Blue light-emission" project of Hoso-Bunka Foundation, Inc., May 1996, (Japan), p.p. 53-60**
Copy of reference (relevant pages): **attached**
English translation: **translation of relevant portions attached**

Latest progress in nitride-based blue/green LED and semiconductor laser

Shuzi Nakamura

Abstract

This is to report a successful development of high luminous intensity InGaN single quantum well (SQW) blue/green LED. Luminous intensity is 2 and 6 candelas, respectively. As a result, in three primaries of green, blue and red, LEDs of candela class are realized. By combining with the existing high luminous intensity AlInGaP red LED, white light source, full color display, and various applications are expected by making use of the features of LED such as high reliability and long life. Moreover, by using the InGaN multiple quantum well (MQW) structure as the luminous layer, for the first time in the world, we succeeded in room temperature pulse oscillation of the nitride-based semiconductor laser diode of blue-violet color. The oscillation wavelength of 420 nm is the shortest oscillation wavelength among the existing semiconductor lasers.

FIG. 6 Structure of InGaN MQW structure laser diode.